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AUTHOR Duran, Richard P.
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ABSTRACT

The present paper describes results of a study that investigated 209 bilingual Puerto Rican college students' ability to solve verbal deductive reasoning problems administered in Spanish and English in relation to their reading comprehension skills in either language. A series of confirmatory factor analyses revealed that the data on reasoning and reading test scores in either language was best accounted for by a theoretical model that presupposed that a common set of skills was involved in solving deductive reasoning problems in either language. Reading comprehension skills in Spanish and English were found to constitute two separate ability factors among bilingual subjects. (Author)

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Bilinguals' Skill in Solving Logical Reasoning Problems in Two Languages

Richard P. Duran

Educational Testing Service

Princeton, New Jersey

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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Introduction

Inspection of two major reviews of research on bilingualism and psychological phenomena by Lambert (1977) and Segalowitz (1977) reveals very little recent research contrasting bilinguals' skill in solving similar or identical reasoning problems in two different languages. Exceptions to this lack of concern have been relatively dated studies by Macnamara (1967) and Macnamara and Kellaghen (1968) investigating Gaelic-English bilinguals' ability to solve verbal arithmetic studies in their two languages. More recently, d'Anglejan and Tucker (1975) reported a study of French-English Canadian adults' ability to solve syllogism problems in their two languages. The results of all of the work mentioned have tended to show that bilinguals are slower in solving problems in their second, weaker language than in their first, dominant language. Macnamara (1967) and Macnamara and Kellaghen (1968), found that their grade school subjects solved fewer arithmetic problems correctly in English than Gaelic, while d'Anglejan and Tucker (1975) found that adults' success in solving simple syllogisms was equivalent across their two languages, though they performed slower in their second language.

The present paper describes the results of a recent study by Duran (1979) which investigated bilingual Puerto Rican college students' ability to solve deductive reasoning problems in Spanish and English, along with subjects' reading comprehension skills in Spanish and English. In the current study, bilingual subjects were administered four matched pairs of deductive reasoning tests in Spanish and English representing skills in syllogism and nonsense syllogism solution, perception of category relationships among classes of objects, and deductive inference-making from text. Reading comprehension performance in each language was reflected by scores on vocabulary recognition, speed of reading, and skill in recognizing paraphrase of meaning. The objective of the research was to determine whether intercorrelations among deductive reasoning scores and reading comprehension scores were accounted for best by one of three alternative factor models. The methodology used was confirmatory maximum likelihood factor analysis which allows specification and estimation of factor models that constrain which variables are permitted to load on given factors and how factors may be intercorrelated.

Model I postulated that intercorrelations among all scores were accounted for by a single general ability or g-factor regardless of the content or language of instruments.

Model II postulated that intercorrelations among scores reflected a general logical reasoning factor, common to all deductive reasoning tests in both Spanish and English, and two separate factors reflecting reading comprehension skills in Spanish and English respectively as well. In specifying Model II, deductive reasoning test scores in a language, in addition to loading on the hypothesized logical reasoning factor, were also allowed to load on the reading comprehension factor in the same language. Additionally, Model II permitted all three factors specified to be intercorrelated.

Model III was similar in structure to Model II except that it hypothesized that there were separate logical reasoning factors in each language rather than just a single reasoning factor. The strategy for deciding which factor model best accounted for intercorrelation among scores was to assess and interpret the statistical goodness of fit of each model. This strategy also involved assessing the improvement of statistical fit in going from a model that posited fewer factors to one positing more factors.

Method

Subjects

Two hundred nine Puerto Rican Spanish-English bilingual students served as paid subjects. Students were sampled from approximately 21 colleges in the states of Connecticut, New York, New Jersey, Pennsylvania, and Virginia. The majority of students, 175 out of 209 (83.7 percent), were enrolled in four-year institutions, while the remainder were enrolled in two-year schools. About 58 percent of all subjects were born in the U.S., while the remainder had been born in Puerto Rico. Prior to college, the subjects overall had averaged 4.3 years of schooling on Puerto Rico and 7.7 years of schooling on the U.S. mainland. All students participating in the study were bilingual in their ability to read, but 47.8 percent of subjects judged that they were more proficient in reading English than in reading Spanish, and roughly equal numbers (24.9 percent and 26.3 percent) indicated that they, respectively, read best in Spanish or equally well in both languages.

Instruments

The deductive reasoning tests in the present study were Nonsense Syllogism Test, Diagramming Relationships, Inference Test, and Logical Reasoning. The first three tests were drawn from the factor Logical Reasoning from the Kit of Factor-Referenced Cognitive Tests (Ekstrom, French and Harman, 1976). The fourth test was drawn from the factor Syllogistic Reasoning from the

earlier Kit of Reference Tests for Cognitive Factors (French, Ekstrom and Price, 1963).

Spanish versions of deductive reasoning tests were developed by a translation team of three persons who were familiar with both standard Spanish and urban vernacular Puerto Rican Spanish spoken in both Puerto Rico and the U.S. The general consensus of the translation team was that the Spanish versions of logical reasoning items were adequate, in being intelligible to Puerto Ricans raised only in the U.S., though the translations on occasion might not have conformed to the highest standards of idiomatic usage among those Puerto Ricans schooled entirely in Spanish on Puerto Rico.

Each subject was administered either Part I or Part II of the four deductive reasoning tests in question. If subjects received Part I of a test in one language, they accordingly received Part II in the other language. Order of presentation of Part I and Part II of tests and language of parts was counterbalanced across subjects.

Reading comprehension instruments administered in Spanish and English, respectively, were the Prueba de Lectura, Nivel 5-Advanzado-Forma DEs and the Test of Reading Level 5-Advanced-Form CE (Guidance Testing Associates, 1962) . Each of these reading comprehension instruments yields subscores pertaining to skills reflecting vocabulary knowledge, reading speed and paraphrase recognition. The two advanced reading tests

administered were considered to be particularly appropriate because they had been developed originally for use with adult and advanced grade level Puerto Rican students. (However, no doubt, due to the age of tests [16 years], they could now profit from renorming.)

Results

Psychometric Characteristics of Test Data

Tables 1 and 2 display the mean score, standard deviation of scores and coefficient alpha reliabilities estimates of scores on Form 1 (i.e., Part I) and Form 2 (i.e., Part II) of logical reasoning tests administered in each language. Although the coefficient alpha reliability

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Insert Tables 1 and 2 about here

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estimates for the various tests were low by applied psychometric standards, since they ranged from the high seventies to low eighties, the obtained coefficients were judged as adequate given the exploratory and theoretical character of the work described.

Table 3 displays means, standard deviations and coefficient alpha reliability estimates for sub scores on Spanish and English reading comprehension tests. Coefficient alpha reliability estimates ranged from the low eighties to low nineties for these measures.

Insert Table 3 about here

Table 4 displays intercorrelations among all logical reasoning test scores in Spanish and English, and subscores on the Spanish and English reading comprehension tests. Accounting for these correlations in terms of a parsimonious

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Insert Table 4 about here

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underlying factor structure was the goal of the work described.

The results of the Model I factor analysis, which posited that intercorrelations among all logical reasoning test scores and comprehension test scores could be accounted for by a single general ability or g-factor are shown in Table 5. The factor pattern matrix reveals that most measures

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Insert Table 5 about here

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load highly on the single factor as would be expected given the nature of the measures. Inspection of the estimates of unique components of variance for each measure and the accompanying Chi-square goodness of fit statistic reveal that Model I did not fit the data well.

Lack of fit of Model I to the intercorrelation matrix of test scores is further evidenced by noting the large size of the residual correlations for Model I shown in Table 6.

Insert Table 6 about here

The magnitude of the residual correlations reflect the difference between observed intercorrelations among scores and intercorrelations estimated based on the factor model which was specified.

Table 7 shows the results of the Model II factor analysis which hypothesized that the data manifested a single logical reasoning factor, loading only on logical reasoning test scores, and two separate Spanish reading comprehension and English reading comprehension factors. The latter factors

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Insert Table 7 about here

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were allowed to load on all test scores reflecting use of one language, or the other

The factor pattern matrix for Model II given in Table 7 shows a meaningful pattern of results, with all logical reasoning measures loading moderately--except for two scores--in the expected direction on the logical reasoning factor. In addition, the pattern of loadings for factors two and three representing skill in reading Spanish and English respectively, shows highest loadings as expected on reading comprehension scores in each language. The Chi-square goodness of fit statistic reveals a dramatic improvement in the fit of Model II over Model I. This is revealed by the drop in the value of the goodness of fit Chi-square statistic for Model II over the Chi-square goodness of fit statistic for Model I, relative to the change

in the degrees of freedom between Models I and II.

We note that the difference in Chi-square values between Models I and II is 243.26, but that the change in degrees of freedom between Models I and II was 77 - 66 = 11. Thus the drop in Chi-square goodness of fit measure exceeds the statistically expected drop between two independent Chi-square values of 11 points, in this case, by many times. Inspection of the matrix of residual correlations for Model II given in Table 8* reveals that the model was fairly successful in reproducing the original correlation matrix.

As one further point, note back on Table 7 that the correlation among factors is substantial, and that the two reading comprehension factors in Spanish and English are more highly correlated with each other, than each is correlated with the single reasoning factor.

Factor Model III was identical to Factor Model II except that it postulated that two separate logical reasoning factors, respectively, in Spanish and English in addition to two separate reading comprehension factors in each language. As with Model II, in Model III deductive reasoning scores were allowed to load both on a logical reasoning factor (here the reasoning factor in the same language) and a reading comprehension factor in the same language.

An attempt to fit Model III to the data failed, because the COFAMM computer program (Sörbum and Jöreskog (1976)) was unable to invert the information matrix during model

*Insert Table 8 about here.

estimation. Failure in the estimation procedure was not due to specification of Model III as all of its parameters were uniquely identified.

As an alternative to Model III, a new model, Model IV was fit to the data using the COFAMM program. This model was identical to Model III, except that it did not permit deductive reasoning measures to load on a reading comprehension factor in the same language. While not ideal, this new model in some sense embodied the notion that the data consisted of separate but correlated factors reflecting logical reasoning and reading comprehension in each language.

The results of fitting Model IV to the intercorrelation matrix of scores are given in Table 9. While the factor

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Insert Table 9 about here

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pattern matrix obtained for Model IV is meaningful and consistent with the hypothesis that separate logical reasoning and reading comprehension factors exist in the data, the fit itself, as indicated for the Chi-square goodness of fit statistic, is not quite as good as the fit obtained with Model II which postulated three factors, rather than four factors. Support for Model II over Model IV is also given by the fact that Model IV estimates that the separate logical reasoning factors in Spanish and English which were estimated, themselves correlated .984.

Conclusion

The results reported in this paper provide some preliminary evidence for the hypothesis that bilinguals' ability to solve highly related verbal reasoning problems in two languages may involve application of a common set of thinking skills to solve problems, and that these skills in themselves may be separable from reading comprehension skills required to understand verbal problems in each of two languages. Such a hypothesis is consistent with emerging theories of bilingualism rooted in cognitive psychology which posit that bilinguals possess a single semantic information memory store for knowledge, and that this memory store is not necessarily always compartmentalized by the language in which knowledge was originally obtained.

TABLE 1

MEANS, STANDARD DEVIATIONS AND ESTIMATED RELIABILITY COEFFICIENTS OF SCORES ON LOGICAL REASONING TESTS IN SPANISH[a]

Test	Form	Number of Items	Mean Score	Standard Deviation	Coefficient α Reliability Estimate
Spanish	1	15	6.67	2.44	.49
Nonsense	2	15	7.09	2.46	.43
Syllogisms	1 and 2 pooled	15	6.92	2.42	---
Spanish	1	15	5.14	2.80	.63
Diagramming	2	15	5.77	2.77	.45
Relationships	1 and 2 pooled	15	5.45	2.54	---
Spanish	1	10	3.26	2.01	.51
Inference	2	10	4.28	2.14	.58
Test	1 and 2 pooled	10	3.80	2.18	---
Spanish	1	20	7.49	3.69	.70
Logical	2	20	7.59	4.40	.77
Reasoning	1 and 2 pooled	20	7.48	3.89	---

[a] N = 98 subjects for Form 1 tests and N = 111 for Form 2 tests.

TABLE 2

MEANS, STANDARD DEVIATIONS AND ESTIMATED RELIABILITY COEFFICIENTS OF SCORES ON LOGICAL REASONING TESTS IN ENGLISH[a]

Test	Form	Number of Items	Mean Score	Standard Deviation	Coefficient α Reliability Estimate
English	1	15	7.07	2.31	.40
Nonsense	2	15	7.72	2.54	.50
Syllogisms	1 and 2 pooled	15	7.33	2.44	---
English	1	15	5.36	2.72	.61
Diagramming	2	15	6.32	3.51	.79
Relationships	1 and 2 pooled	15	5.80	3.22	---
English	1	10	3.74	2.08	.53
Inference	2	10	4.70	2.47	.70
Test	1 and 2 pooled	10	4.21	2.33	---
English	1	20	8.80	4.10	.75
Logical	2	20	8.72	4.81	.83
Reasoning	1 and 2 pooled	20	8.73	2.92	---

[a]N = 111 subjects for Form 1 tests and N = 98 for Form 2 tests.

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TABLE 4

CORRELATIONS AMONG LOGICAL REASONING TEST SCORES AND COMPREHENSION SUBSCORES FOR BOTH LANGUAGES

	Spanish Nonsense Syllogisms	Spanish Diagramming Relationships	Spanish Inference Test	Spanish Logical Reasoning	English Nonsense Syllogisms	English Diagramming Relationships	English Inference Test	English Logical Reasoning	Spanish Vocabulary	Spanish Speed	Spanish Level	English Vocabulary	English Speed	English Level
Spanish Nonsense Syllogisms	1.00													
Spanish Diagramming Relationships	.25	1.00												
Spanish Inference Test	.06	.52	1.00											
Spanish Logical Reasoning	.16	.48	.43	1.00										
English Nonsense Syllogisms	.18	.24	.10	.16	1.00									
English Diagramming Relationships	.10	.54	.33	.42	.25	1.00								
English Inference Test	.10	.50	.49	.48	.19	.51	1.00							
English Logical Reasoning	.14	.57	.50	.68	.28	.55	.58	1.00						
Spanish Vocabulary Spanish Speed	.05	.48	.49	.47	.07	.35	.47	.37	1.00					
Spanish Speed	.16	.44	.49	.45	.19	.36	.42	.39	.74	1.00				
Spanish Level	.07	.52	.48	.44	.18	.47	.49	.45	.74	.72	1.00			
English Vocabulary	.07	.53	.54	.47	.17	.51	.68	.55	.71	.52	.60	1.00		
English Speed	.14	.54	.56	.45	.22	.53	.60	.55	.61	.61	.58	.81	1.00	
English Level	.07	.56	.60	.49	.21	.59	.66	.60	.54	.46	.59	.77	.76	1.00

TABLE 5

MODEL I FACTOR ANALYSIS

Variable Number	Variable Name	Factor Pattern Matrix Factor 1 General Intelligence
1.	Spanish Nonsense Syllogisms	.141
2.	Spanish Diagramming Relationships	.678
3.	Spanish Inference Test	.668
4.	Spanish Logical Reasoning	.613
5.	English Nonsense Syllogisms	.248
6.	English Diagramming Relationships	.636
7.	English Inference Test	.737
8.	English Logical Reasoning	.688
9.	Spanish Vocabulary	.741
10.	Spanish Speed	.677
11.	Spanish Level	.738
12.	English Vocabulary	.870
13.	English Speed	.856
14.	English Level	.847

	1	2	3	4	5	6	7
Uniquenesses:	.980	.541	.554	.624	.939	.595	.457
	8	9	10	11	12	13	14
	.526	.451	.541	.455	.242	.268	.282

Fit of Model: X^2(77 df)= 425.132, p = 0.00

TABLE 6

RESIDUAL CORRELATIONS FOR FACTOR MODEL I

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	.000													
2	.155	.000												
3	-.034	.068	.000											
4	.076	.068	.020	.000										
5	.142	.067	-.063	.011	.000									
6	.013	.109	-.074	.031	.097	.000								
7	-.001	-.001	-.001	.032	.004	.044	.000							
8	.044	.103	.042	.253	.106	.113	.075	.000						
9	-.057	-.021	-.005	.015	-.109	-.120	-.072	-.145	.000					
10	.063	-.023	.039	.035	.024	-.070	-.079	-.077	.241	.000				
11	-.032	.015	-.014	-.010	.001	.001	-.058	-.062	.196	.222	.000			
12	-.052	-.060	-.040	-.067	-.051	-.044	.034	-.054	.063	-.070	-.039	.000		
13	.022	-.045	-.010	-.078	.010	-.014	-.029	-.042	-.027	.025	-.051	.070	.000	
14	-.050	-.014	.033	-.034	.004	.054	.036	.020	.090	-.116	-.037	.034	.034	.000

TABLE 8

RESIDUAL CORRELATIONS FOR FACTOR MODEL II

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	.000													
2	.125	.000												
3	-.047	.061	.000											
4	.026	-.034	-.032	.000										
5	.120	.035	-.069	-.055	.000									
6	-.013	.095	-.049	-.047	.065	.000								
7	-.019	.008	.042	-.022	-.015	.018	.000							
8	-.029	-.021	-.001	.026	.004	-.007	-.004	.000						
9	-.042	-.023	-.030	.011	-.040	-.057	-.022	-.041	.000					
10	.076	-.033	.008	.024	.058	-.018	-.041	.011	.005	.000				
11	-.013	.037	-.014	.007	.047	.083	.015	.060	-.011	.021	.000			
12	-.048	.001	.037	-.057	-.037	-.043	.013	-.029	.076	-.067	.004	.000		
13	.028	.022	.072	-.062	.026	-.006	-.042	-.011	-.007	.035	-.002	.010	.000	
14	-.043	.060	.122	-.009	.023	.070	.034	.060	-.059	-.097	.022	-.012	-.002	.000

Table 9

Model IV Factor Analysis

Variable Number	Variable Name	Factor Pattern Matrix Factor 1 Spanish Logical Reasoning	Factor 2 English Logical Reasoning	Factor 3 Spanish Reading Comprehen.	Factor 4 English Reading Comprehen.
1.	Spanish Nonsense Syllogisms	.178	0.0	0.0	0.0
2.	Spanish Diagramming Relationships	.728	0.0	0.0	0.0
3.	Spanish Inference Test	.661	0.0	0.0	0.0
4.	Spanish Logical Reasoning	.698	0.0	0.0	0.0
5.	English Nonsense Syllogisms	0.0	.283	0.0	0.0
6.	English Diagramming Relationships	0.0	.677	0.0	0.0
7.	English Inference Test	0.0	.758	0.0	0.0
8.	English Logical Reasoning	0.0	.795	0.0	0.0
9.	Spanish Vocabulary	0.0	0.0	.891	0.0
10.	Spanish Speed	0.0	0.0	.832	0.0
11.	Spanish Level	0.0	0.0	.847	0.0
12.	English Vocabulary	0.0	0.0	0.0	.907
13.	English Speed	0.0	0.0	0.0	.887
14.	English Level	0.0	0.0	0.0	.861

		1	2	3	4
Correlations Among Factors	1	1.000			
	2	.984	1.000		
	3	.784	.641	1.000	
	4	.838	.872	.773	1.000

	1	2	3	4	5	6	7
Uniquenesses:	.968	.470	.563	.512	.920	.542	.426
	8	9	10	11	12	13	14
	.368	.206	.308	.282	.178	.213	.259

Fit of Model: $\underline{X}^2(\ 71\ \underline{df}) = 214.76,\ \underline{p} = 0.00$

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